Actuated Payload Design for an Icosahedron Tensegrity Structure

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Project Summary

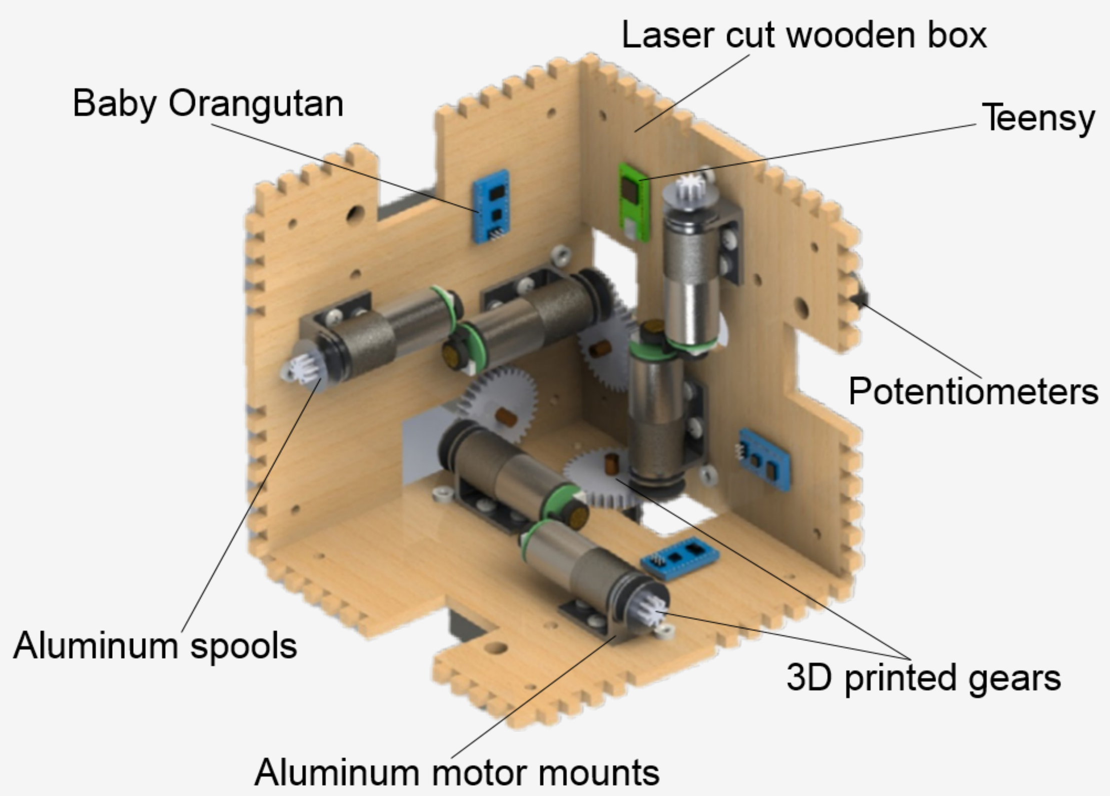
Design, manufacture, and test a low-cost actuated payload for a six-strut Icosahedron tensegrity structure capable of movement within the structure as well as inducing tipping for locomotion purposes.

Tensegrity Background

Tensegrity, or “integrity through tension,” is the concept of connecting multiple rigid struts only through a network of tension cables. The lack of any rigid connections leads to a natural compliance, lending itself to the possibility of a hybrid lander/rover system. Other promising attributes include a high payload to system mass ratio, naturally redundant mobility systems, and ability to absorb large impacts. The development of an actuated payload not only can serve as an alternative locomotion method, but also as a fine position system for sensors.

Payload Design

The final design, shown in figure 1 below, consists of 6 laser-cut identical walls. Each wall contains two brushed DC motors, 1 Baby Orangutan Microcontroller/ H-bridge, and 2 geared multi-turn potentiometers. In addition, 1 wall contains a single Teensy 3.1 microcontroller.



Payload Mass	3 kg
Battery Mass	0.4 kg
Scientific Mass	2.6 kg

Figure 1. A cutaway of a CAD model showing half of the designed payload.

System & Software Architecture

The Teensy 3.1 serves as a master, determining the necessary string lengths and delivering them to the correct walls. Each Baby Orangutan serves as a slave, taking the given string length as well as the position data from the potentiometers and driving the spool to the new location.

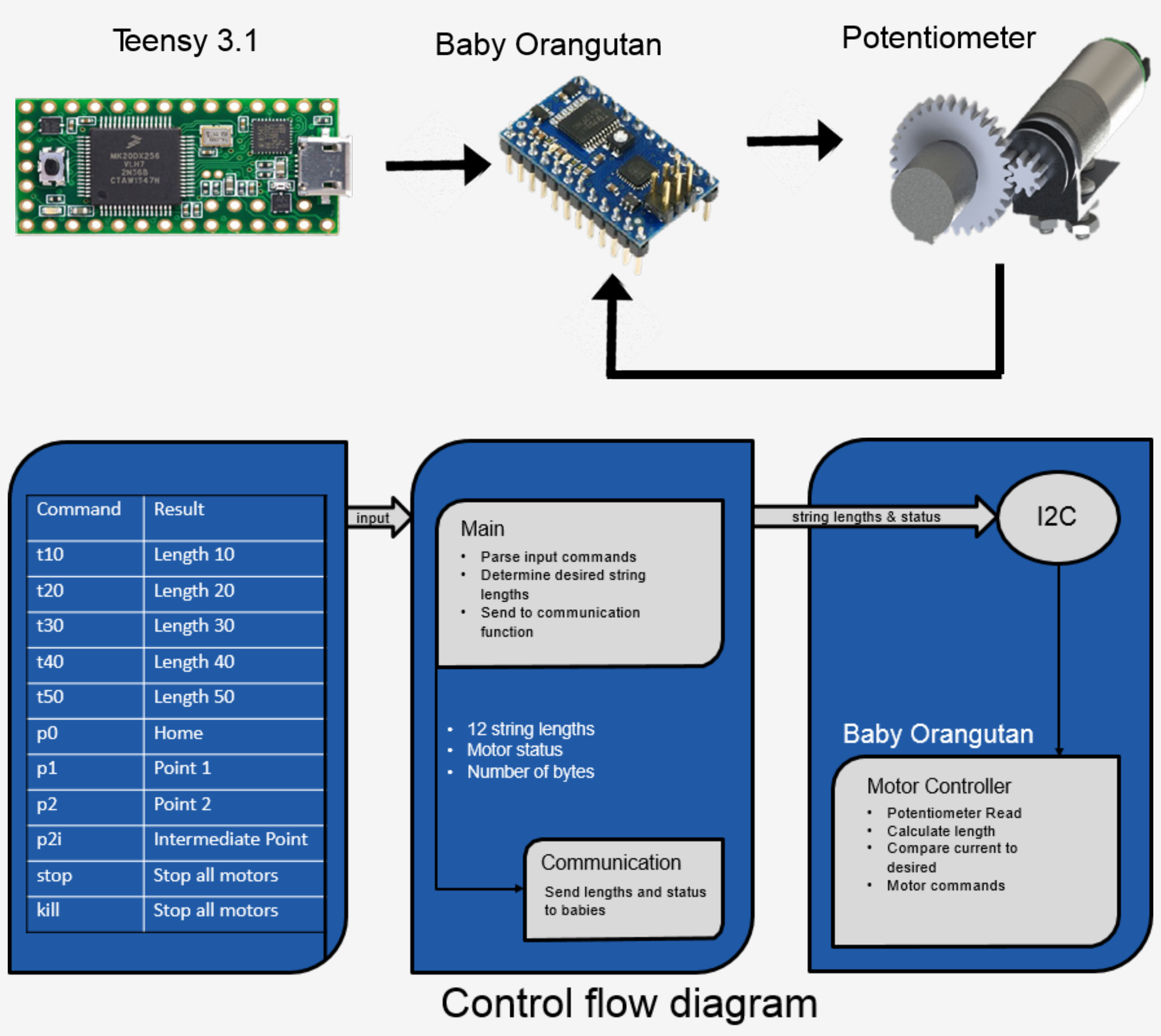


Figure 2. Information flow through software and hardware.

Tipping Model Validation

A geometric model of the payload and tensegrity structure was developed in Matlab to serve as an aid to determine tipping locations. Using this tool, estimate string lengths were found and programmed into the payload. Fine tuning of the exact strings lengths was then performed to ensure consistent tipping.

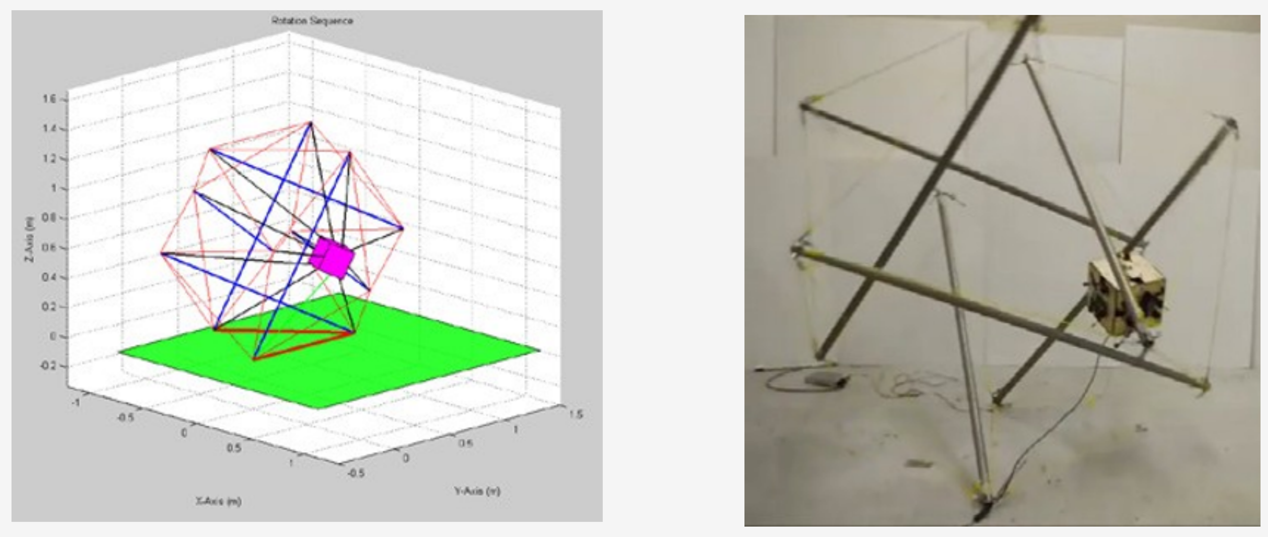


Figure 3. Pictures of the Matlab model showing estimate strings length as well as the payload mounted in the tensegrity structure.

Payload Routing

Icosahedron Tensegrities have 20 faces, but only two unique ones: open face and closed face. As such, two different sets of tipping point string lengths were found and re-ordered for the other 18 faces. Due to the location of the struts in the closed face location, an intermediary point is used to route the payload clear of the strut.

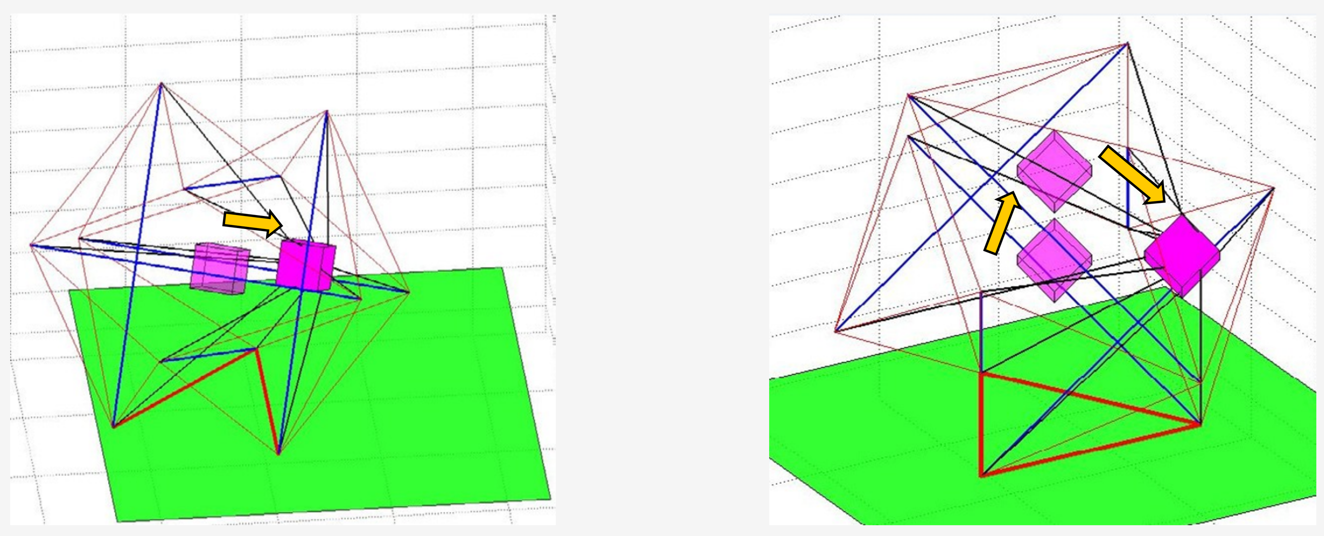


Figure 4. The Matlab diagrams showing the two tipping locations. The open base configuration is on the left, the closed base is on the right.

Results

Successful tipping was achieved in both the opened face and closed face triangles. Tipping over the long edge of the open face triangle was highly consistent and repeatable. Tipping over the closed face triangle proved more difficult due to the wider footprint of the three vertices.

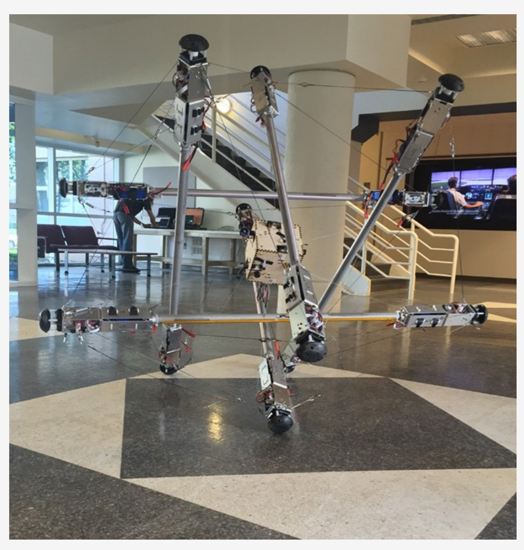


Figure 4. The payload attached inside NASA’s SUPERball tensegrity robot.

Due to the payload translating a farther distance in the closed face configuration, the payload had a more violent landing. Early design decisions, mainly materials and adhesives, were prone to failure. Improvements in these problem areas have been identified, but not implemented yet.

Future Work

Currently, we plan on continuing this project in Fall 2015, with an emphasis on redesigning components to be more robust. In addition, we are considering adapting the payload to function in an 8 or 12-strut tensegrity. This would shrink the footprint of the bases, making tipping both quicker and easier on the payload.